PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A61N 5/02	A1	(11) International Publication Number: WO 99/27997
		(43) International Publication Date: 10 June 1999 (10.06.99)

(21) International Application Number: PCT/US98/25412

(22) International Filing Date: 1 December 1998 (01.12.98)

(30) Priority Data:
08/980,625 1 December 1997 (01.12.97) US

(71) Applicant *(for all designated States except US)*: ESC MEDICAL SYSTEMS LTD. [IL/IL]; P.O. Box 240, 20692 Yokneam (IL).

(71) Applicant *(for TJ only)*: FRIEDMAN, Mark, M. [US/IL]; 1 Alharizi, 43406 Raanana (IL).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: KREINDEL, Michael [IL/IL]; 33 Bar Rav Hai David, 35592 Haifa (IL). ECKHOUSE, Shimon [IL/IL]; 27 Rabin Ester, Denya, 34987 Haifa (IL).

(74) Common Representative: FRIEDMAN, Mark, M.; c/o Castorina, Anthony, Suite 207, 2001 Jefferson Davis Highway, Arlington, VA 22202 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: IMPROVED DEPILATORY METHOD AND DEVICE

(57) Abstract

An improved method of hair removal, and associated devices. For the removal of shallow and/or light–colored hair, the targeted skin region is irradiated with light of a wavelength between 550 nm and 680 nm, and an energy density of between 30 J/cm^2 and 100 J/cm^2, for between 1 ms and 100 ms. A targeted area about as wide as the depth of the hair follicles to be destroyed is irradiated using one or more sources, such as lasers, that produce considerably narrower beams, either by scanning one beam across the target or by irradiating the target using several beams simultaneously.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

APPLICATION FOR PATENT

Title: IMPROVED DEPILATORY METHOD AND DEVICE

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to hair removal and, more particularly, to an improved method and device for permanently removing hair using pulses of light.

The use of intense light to heat hairs, and the follicles whence they grow, to temperatures high enough to kill the follicles without appreciable damage to the surrounding tissue, is known. Tankovich, in US Patent No. 5,226,907, teaches a method of hair removal in which the portion of the hair below skin level is coated with a substance such as carbon that absorbs light of selected frequencies (10.6 micron infrared light in the preferred embodiment) than the surrounding tissue. Anderson et al., in US Patent No. 5,595,568, which is incorporated by reference for all purposes as if fully set forth herein, relies on the natural pigmentation of the hair to absorb light in a range of 680 nm to 1200 nm.

With the object of destroying many follicles at once, both Tankovich and Anderson et al. direct a light beam at least on the order of 1 cm wide at each area of skin to be treated. As noted by Anderson et al., the width of the light beam preferably is at least as great as the depth of the follicles to be destroyed. Depending on their specific location, follicles may be between 0.1 mm and 0.5 mm deep. The energy density of the light beam taught by Anderson et al. is between 10 J/cm^2 and 200 J/cm^2, most preferably between 30 J/cm^2 and 50 J/cm^2. Although lasers are readily available that produce beams of coherent light with this width and energy density, it would be advantageous to be able to use less expensive diode lasers, with beam widths as small as 0.05 mm, for this application.

Figure 1 is a plot of the penetration depth of light in skin tissue, as a function of wavelength. Light in the wavelength range taught by Anderson et al., 680 nm to 1200 nm, penetrates skin tissue to depths of 2 mm or greater. Thus, a larger volume of skin tissue is heated than is strictly necessary when destroying follicles shallower than 2 mm, and there is a risk of overheating the surrounding skin tissue.

SUMMARY OF THE INVENTION

According to the present invention there is provided an improved method for removing hairs from a skin region of a patient, including the step of irradiating the skin region with light of a first wavelength shorter than about 680 nm.

According to the present invention there is provided an improved method for removing multiple hairs from a skin region of a patient, each of the hairs being in a corresponding follicle at a certain depth in the skin region, including the step of irradiating a plurality of spots in a portion of the skin region having a lateral extent at least as great as the depth of the follicles, so as to deposit at least about 30 J/cm^2 of energy in the portion of the skin region within a time shorter than about 200 ms.

According to the present invention there is provided a device for sequentially irradiating a plurality of substantially contiguous spots in a two-dimensional pattern on a target, including: (a) a source of light; and (b) a mechanism for sequentially directing the light at each of the spots in the pattern.

According to the present invention there is provided a device for simultaneously irradiating a plurality of substantially contiguous spots in a two-dimensional pattern on a target, including: (a) an array of apertures congruent with the pattern; (b) at least one light source; and (c) a mechanism for optically coupling the at least one light source with the apertures.

Figure 2 shows experimentally measured absorption coefficients of hair of four different colors, as a function of wavelength. In the especially preferred wavelength range of Anderson et al., 800 nm - 900 nm, the absorption coefficient of dark (black, red or brown) hair is between about 50 cm^{-1} and about 70 cm^{-1}, but the absorption coefficient of blond hair is only about 25 cm^{-1}. To obtain, for blond hair, the light absorption obtained in dark hair by the method of Anderson et al., it is necessary to use light in the wavelength range of the present invention, 550 nm to 680 nm. Thus, the wavelength range of the present invention is preferred over the prior art wavelength range, both for shallow hair and for blond hair. Light in the wavelength range of the present invention may be supplemented by light in the prior art wavelength range for removing shallow dark hair. The preferred energy density and pulse length are similar to those of the prior art: an energy density between about 30 J/cm^2 and about 100 J/cm^2, and a pulse length between about 1 ms and about 100 ms. The upper end of this time span is the maximum expected thermal relaxation time of a hair follicle enclosed in dermal fat.

In the second aspect of the present invention, the therapeutic beams of light are created by diode lasers, or similar sources, that produce collimated beams of light that are narrower than the desired depth of penetration. To achieve the desired effective beamwidth, the beam or beams are directed at multiple spots within a region of skin whose lateral extent is as great as the desired depth of penetration. One beam may be directed sequentially at several spots within the region, or several beams may be directed simultaneously at the several spots within the region, as long as the desired energy density of at least about 30 J/cm^2 is deposited within the desired time of no more than about 200 ms.

The preferred range of spot diameters within the scope of the present invention is between about 0.5 mm and about 5 mm. A spot as small as 0.5 mm in diameter may require an energy density as high as about 1000 J/cm^2.

The scope of the present invention also includes devices for effecting this irradiation with an effective beamwidth wider than the collimated beam produced by the light source. In one embodiment of the device, a diode laser is optically coupled to a proximal end of an optical waveguide that is about as wide as the collimated beam produced by the laser, and the other, distal end of the waveguide is scanned across the target region. In another embodiment, several diode lasers are optically coupled to the proximal ends of several optical waveguides, and the distal ends of the waveguides are bundled in a two dimensional pattern that is as wide as the desired effective beamwidth. Most preferably, the distal ends of the waveguides are inserted in a spacer which, when held against the target, holds the distal ends of the waveguide stationary with respect to the target and at a fixed distance from the target.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 is a graph showing the penetration depth of light of various wavelengths in skin tissue;

FIG. 2 is a graph showing the absorption coefficient of hair of various colors as a function of wavelength;

FIG. 3 shows an irradiation pattern of the present invention superposed on a prior art irradiation pattern;

FIG. 4 is a schematic depiction, partly in perspective, of a first device of the present invention;

FIG. 5 is a schematic depiction, partly in perspective, of a second device of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of a method and device which can be used to remove unwanted hair.

The principles and operation of depilation according to the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, Figure 3 shows a square **10** that is 3 mm on a side. Superimposed thereon is a pattern of **16** partly overlapping circles **12**, each 1 mm in diameter, for the equivalent irradiation of a skin region according to the present invention. To deposit 30 J/cm^2 of light energy in the area of square **10** within 75 msec requires a 36W laser. To deposit the same 30 J/cm^2 sequentially in circles **12** within 75 msec (4.7 msec per circle) requires a 50W laser. To deposit the same 30 J/cm^2 simultaneously in circles **12** within 75 msec requires 16 3W lasers.

Figure 4 shows, schematically, a device **20** for effecting the sequential irradiation of circles **12**. The mechanical portion of device **20** is based on a rigid hollow rectangular frame **22**. Rising from three of the corners of frame **22** are three towers **24**, **26** and **28**. Tower **24** supports a stepping motor **36** which rotates a mirror **30** about a vertical rotation axis. From tower **26** projects an arm **34** which supports a second stepping motor **38**. Stepping motor **38** rotates a mirror **32** about a horizontal rotation axis. Tower **28** supports a clamp **40** which secures a distal end **46** of an optical waveguide **44** to tower **28** so that distal end **46** of optical waveguide **44** points at mirror **30**. Waveguide **44** is circular in cross section and 1 mm in diameter. The combined rotations of mirror **30** in a horizontal plane and mirror **32** in a vertical plane directs light emerging from distal end **46** of optical waveguide **44** to any desired lateral position within the interior of frame **22**.

A proximal end **48** of waveguide **44** is optically coupled to a laser **50** having an output power of 50W. Laser **50** is energized and controlled by a microprocessor-based control system **52** via a power/control line **54**. Stepping motors **36** and **38** are energized and controlled by control system **52** via a power/control line **56**.

To use device **20**, frame **22** is positioned to enclose the targeted skin region. Control system **52** then sequentially rotates mirrors **30** and **32** to direct the light emerging from distal end **46** to each of circles **12** in the pattern of Figure 3, spending 4.7 msec at each circle **12** while firing laser **50**. Distal end **46** functions in combination with mirrors **30** and **32** as an optical aperture, wherefrom light from laser **50** emerges to irradiate the target. Laser **50** may be pulsed, with the pulses thereof synchronized with the rotations of mirrors **30** and **32** so that the pulses are directed at each of circles **12**. Alternatively, laser **50** may operate continuously, with mirrors **30** and **32** providing a dwell time of 4.7 msec at each of circles **12**.

Figure 5 is a partial schematic depiction of a device **60** for effecting the simultaneous irradiation of circles **12**. 16 fiber optic waveguides **64**, each of circular cross section and 1 mm in diameter, are arranged in a bundle **62** so that distal ends **66** of waveguides **64** are deployed in the pattern of circles **12** of Figure 3. Distal ends **66** of waveguides **64** are inserted together in a proximal end **74** of a hollow rectangular sleeve **70**. When a distal end **76** of sleeve **70** is placed adjacent to a targeted skin region, sleeve **70** keeps distal ends **66** of waveguides **64** at the desired distance from the target. A proximal end **68** of each waveguide **64** is optically coupled to a separate 3W diode laser **72**. With sleeve **70** in place above the target, lasers **72** are fired simultaneously for 75 msec. Distal ends **66** serve as apertures, wherefrom light from lasers **72** emerges to irradiate the target.

Diode lasers suitable for implementing the various aspects of the present invention are manufactured by a variety of manufacturers, for example Applied Optronics Corporation.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

WHAT IS CLAIMED IS:

1. An improved method for removing hairs from a skin region of a patient, comprising the step of irradiating the skin region with light of a first wavelength shorter than about 680 nm.

2. The method of claim 1, wherein said first wavelengths longer than about 550 nm.

3. The method of claim 1, further comprising the step of irradiating the skin region with light of a second wavelength longer than about 680 nm.

4. The method of claim 1, wherein said light has an energy density, on said skin region, of between about 30 J/cm^2 and about 1000 J/cm^2.

5. The method of claim 1, wherein said light is directed at the skin region in at least one pulse having a duration of between about 1 ms and about 200 ms.

6. An improved method for removing multiple hairs from a skin region of a patient, each of the hairs being in a corresponding follicle at a certain depth in the skin region, comprising the step of irradiating a plurality of spots in a portion of the skin region having a lateral extent at least as great as the depth of the follicles, so as to deposit at least about 30 J/cm^2 of energy in said portion of the skin region within a time shorter than about 200 ms.

7. The method of claim 6, wherein each of said plurality of spots has a diameter between about 0.5 mm and about 5 mm.

8. The method of claim 6, wherein said irradiating is effected using light having a wavelength between about 550 nm and about 680 nm.

9. The method of claim 6, wherein said irradiating is effected using light having a wavelength between about 680 nm and about 1000 nm.

10. The method of claim 6, wherein said irradiating of said plurality of spots is effected substantially simultaneously.

11. The method of claim 6, wherein said irradiating of said plurality of spots is effected sequentially.

12. A device for sequentially irradiating a plurality of substantially contiguous spots in a two-dimensional pattern on a target, comprising:

(a) a source of light; and

(b) a mechanism for sequentially directing said light at each of the spots in the pattern.

13. The device of claim 12, wherein said mechanism includes an aperture wherefrom said light emerges to strike the target.

14. The device of claim 13, wherein said mechanism includes:

(i) an optical waveguide having a proximal end and a distal end, said proximal end being optically coupled to said source of said light, said aperture including said distal end, and

(ii) a mechanism for scanning said distal end across said pattern.

15. A device for simultaneously irradiating a plurality of substantially contiguous spots in a two-dimensional pattern on a target, comprising:

(a) an array of apertures congruent with said pattern;

(b) at least one light source; and

(c) a mechanism for optically coupling said at least one light source with said apertures.

16. The device of claim 15, wherein said mechanism includes a plurality of optical waveguides, each of said optical waveguides having a proximal end and a distal end, each of said proximal ends being optically coupled to one of said at least one light source, each of said apertures including one of said distal ends.

17. The device of claim 16, including a plurality of said at least one light source, wherein each of said optical waveguides is optically coupled to a separate one of said plurality of light sources.

18. The device of claim 15, further comprising:

(d) a spacer for holding said apertures at fixed position relative to the target.

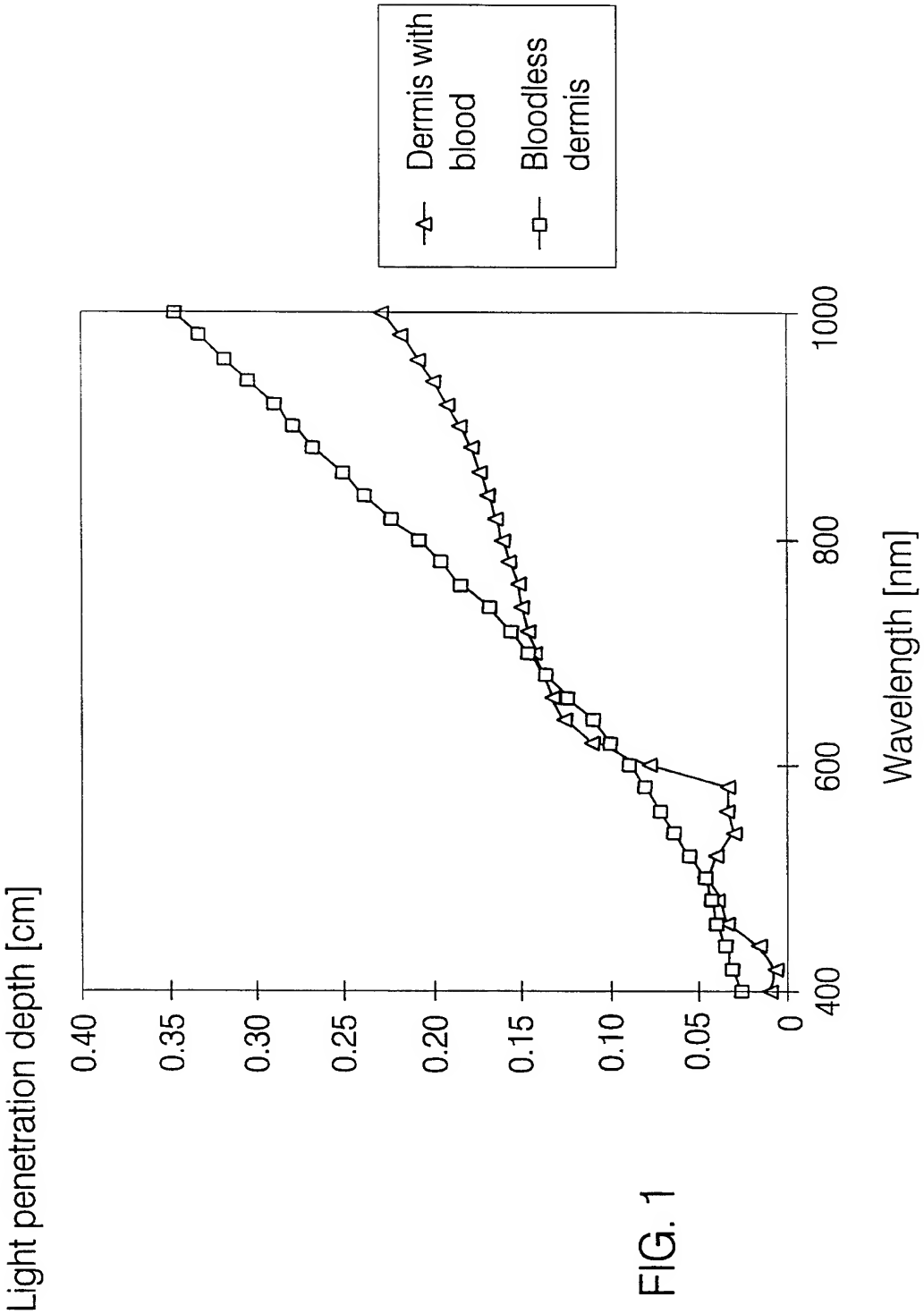
Dermis with blood
Bloodless dermis
Light penetration depth [cm]
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
400
600
800
1000
Wavelength [nm]

FIG. 1

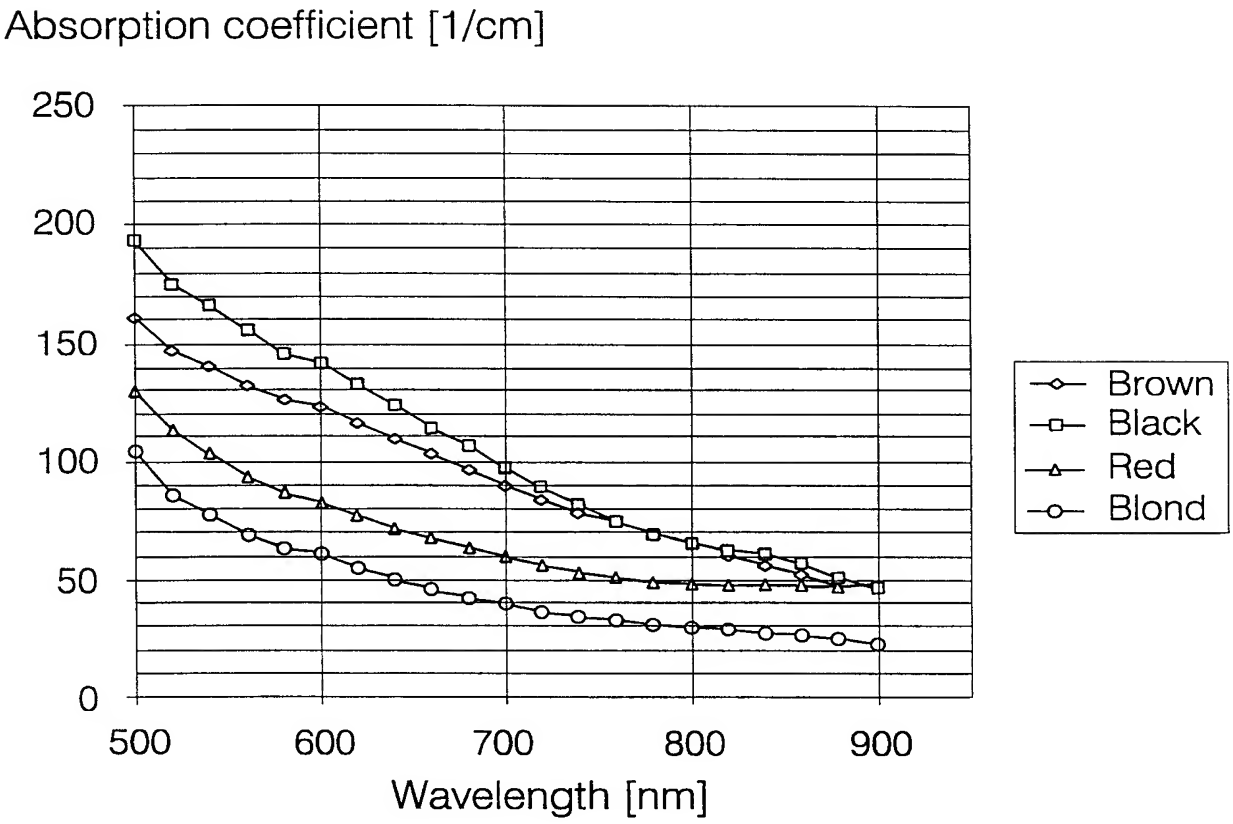
Absorption coefficient [1/cm]
250
200
150
100
50
0
500
600
700
800
900
Wavelength [nm]
Brown
Black
Red
Blond

FIG. 2

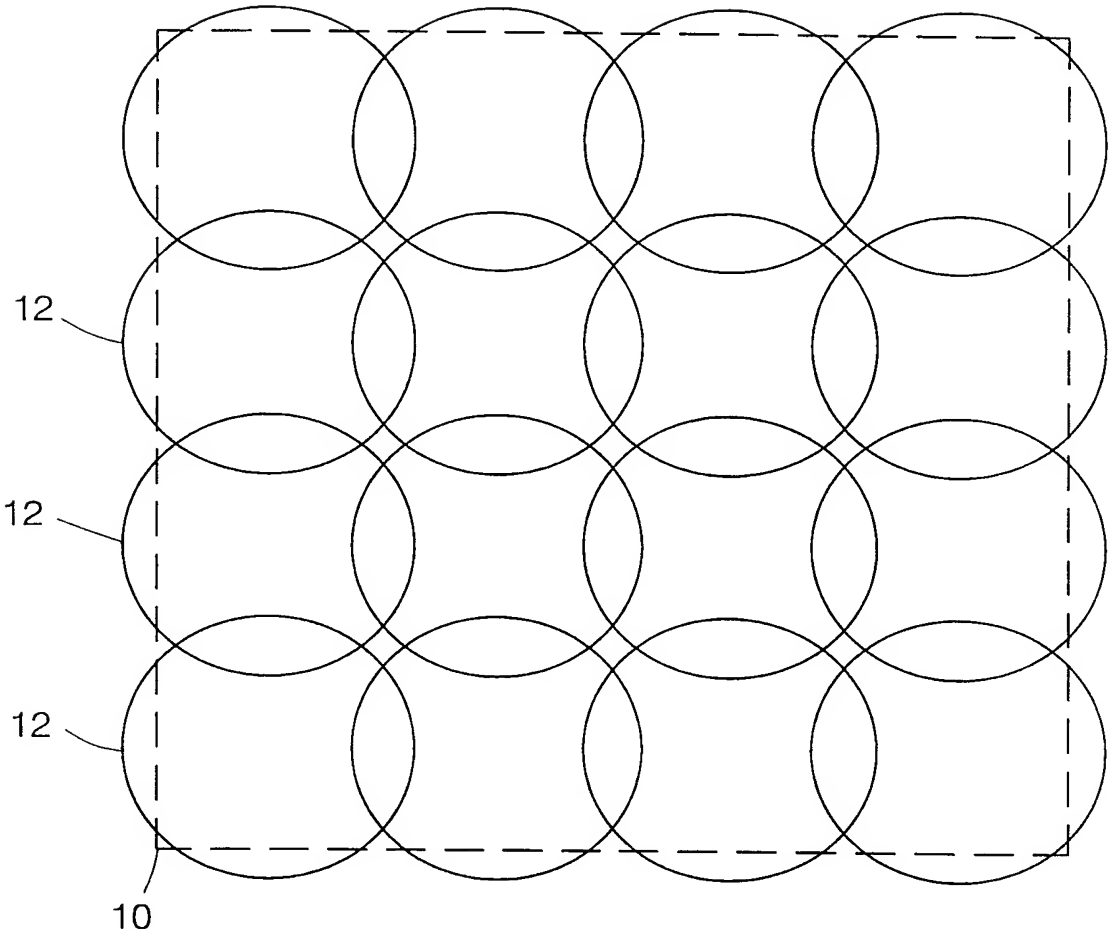

FIG. 3

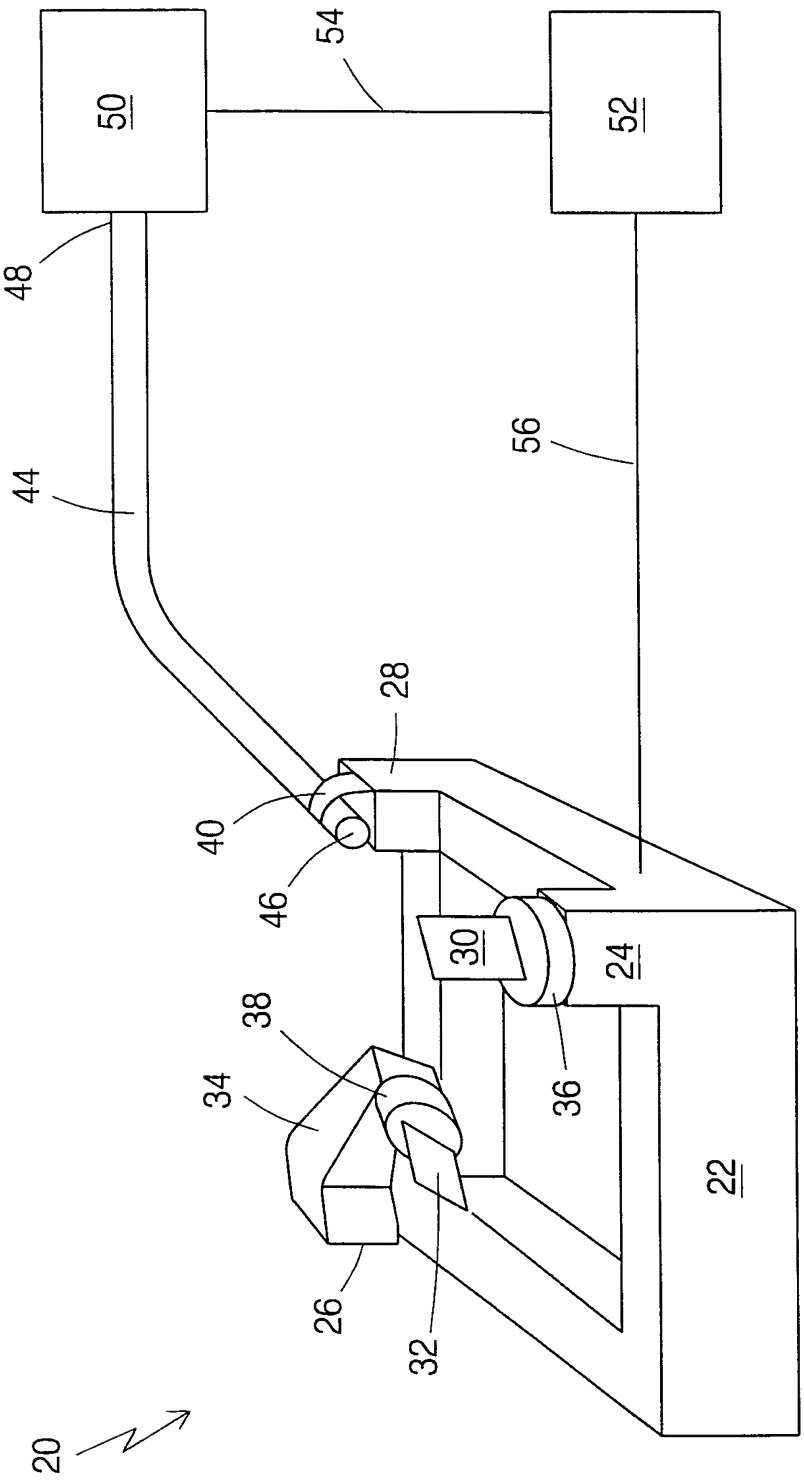

FIG. 4

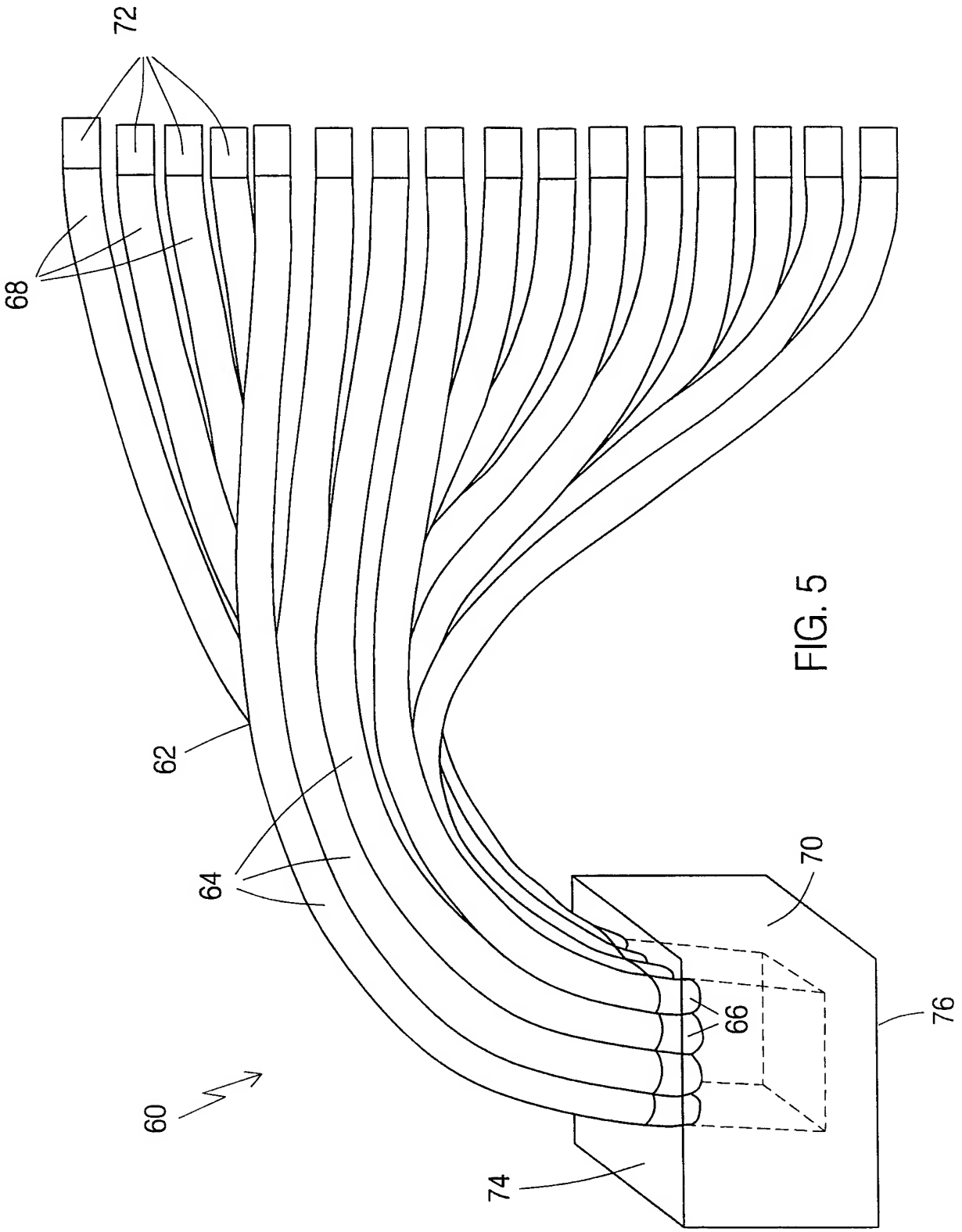

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/25412

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61N 5/02
US CL :606/9

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 606/3-18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,182,857 A (SIMON) 02 February 1993, entire document.	1-13 --- 14-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 14 FEBRUARY 1999	Date of mailing of the international search report 15 MAR 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer DAVID M. SAY Telephone No. (703) 308-2215

Form PCT/ISA/210 (second sheet)(July 1992)★